A Phased Array Tracking Antenna for Vehicles

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ABSTRACT

An antenna system including antenna elements and a satellite tracking method is considered a key technology in implementing land mobile satellite communications. In the early stage of land mobile satellite communications, a mechanical tracking antenna system is considered the best candidate for vehicles, however, a phased array antenna will replace it in the near future, because it has many attractive advantages such as a low and compact profile, high speed tracking and potential low cost. Communications Research Laboratory is now developing a new phased array antenna system for land vehicles based on research experiences of the airborne phased array antenna , which was developed and evaluated in satellite communication experiments using the ETS-V satellite.

This paper describes the basic characteristics of the phased array antenna for land vehicles.

I. INTRODUCTION

An antenna system including antenna elements and a satellite tracking method is considered a key technology in implementing land mobile satellite communications. In the early stage of land mobile satellite communications, a mechanical tracking antenna system is considered the best candidate because of its characteristics such as a simple configuration, a wide beam coverage and an easy installation [1]. However, a phased array antenna will replace it in the near future, because it has many attractive advantages such as a low and compact profile, high speed tracking and potential low cost. On the other hand, it also has such disadvantages as lower G/T caused by complex feed lines, narrow beam coverage and so on.

Communications Research Laboratory is now developing a new phased array antenna system for land vehicles based on research experiences of the airborne phased array antenna [2], which was developed and evaluated in aeronautical satellite communication experiments using the ETS-V satellite [3].

This paper describes the basic characteristics of the phased array antenna for land vehicles.

II. MAIN FEATURES OF THE PHASED ARRAY ANTENNA

The main features of the phased array antenna are as follows:

(1) Antenna elements are excited by electromagnetic coupling with microstrip feed lines. Because of its easy configuration, production cost will be reduced greatly enough for land vehicles including private cars.

(2) A total number of digital phase shifters will be reduced to one-half using a newly developed phase shifter. The phase shifter is printed on a substrate, which will make the present complex feed lines simple. The development of a new phase shifter is in the first stage, where a 3-bit phase shifter with having only 6 PIN-diodes have been developed.

(3) Tracking error between transmitting and receiving frequencies, which is inevitable for a phased array antenna, is potentially eliminated using a frequency dependent phase shifter [4]. The new phase shifter is scheduled to be developed on a second stage of the project.

III. ANTENNA ELEMENT

An electromagnetic coupled antenna is adopted as an antenna element, because it will reduce procedures of assembling the antenna system and it will reduce a cost of the phased array antenna to compete with a conventional mechanical steering antenna. Figure 1 shows a configuration of the antenna element. A feed line is a microstrip line printed on a substrate, which excites a radiating element by electromagnetic coupling through a coupling aperture. A radiating element, which radiates circularly polarized waves, is also printed on a thin film substrate. Figure 2 shows a

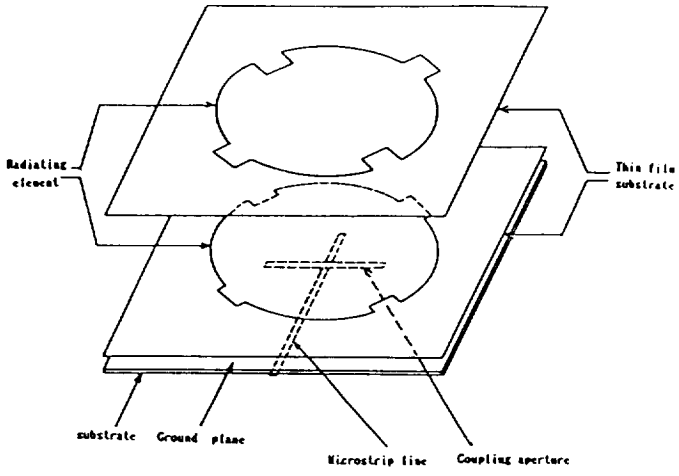

Fig.1 Configuration of Antenna Element.

frequency dependence of return loss of the element. The return loss in the frequency range of 1530-1660.5 MHz, which is required in mobile satellite communications, is found to be below 20 dB.

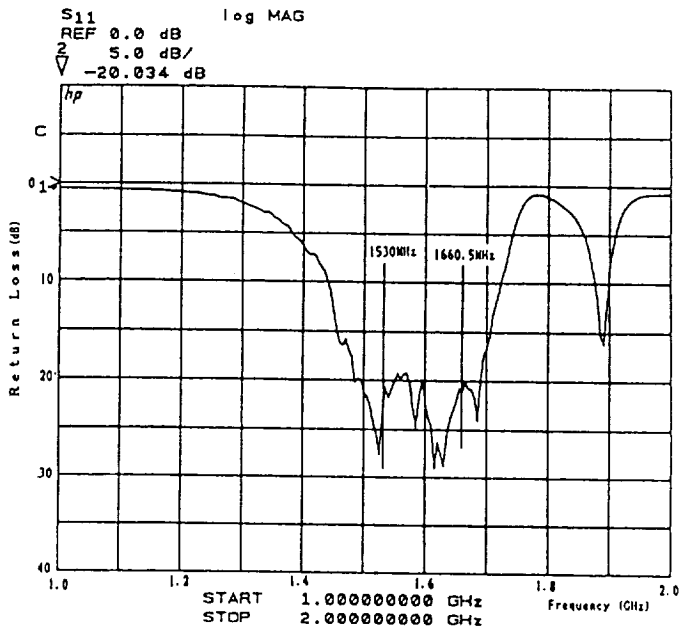

Fig.2 Return Loss of Antenna Element.

IV. PHASED ARRAY

The phased array antenna is under development and a prototype is assembled as shown in Fig. 3. A gain of the array antenna is designed to be 18 dBi in a non-scanned direction (Elevation angle: 90 deg.), and 10 dBi in a scanned angle of 60 degrees (Elevation angle: 30 deg.), which is determined by a system requirement of the ETS-V experiment. Main characteristics of the array antenna are shown in Table 1. The array consists of 19 elements, which are fed by microstrip feed lines as shown in Fig. 4. A theoretical calculation of gains and radiation patterns of the array antenna is shown in Fig. 5, where θ denotes a scanned angle from the boresight direction (Elevation angle: 90 deg). The gain is shown in a directive gain, which does not include losses of feed lines including phase shifters.

Fig.3 Prototype of the Phased Array Antenna.

Tabel.1 Main Characteristic of the Array Antenna

Frequency	f_R 1530.0MHz～1559.0MHz f_T 1626.5MHz～1160.5MHz
Polarization	Left Hand Circular
Scanned Angle	Ele. 30° ～ 90° Az. 0° ～360°
Gain	18dB: (Ele.90°) 10dB: (Ele.30°)
System Temp	200K
Axial Ratio	4dB(Ele.=30°)
Volume	60cmφ×4cm(H)
Weight	5kg

V. TRACKING METHOD

A tracking method of a phased array antenna is a very important key technology in land mobile satellite communications, and two different methods and an integrated method will be evaluated in the ETS-V experiment. First method is a closed loop system, which can track a satellite by receiving a signal from a satellite. Second

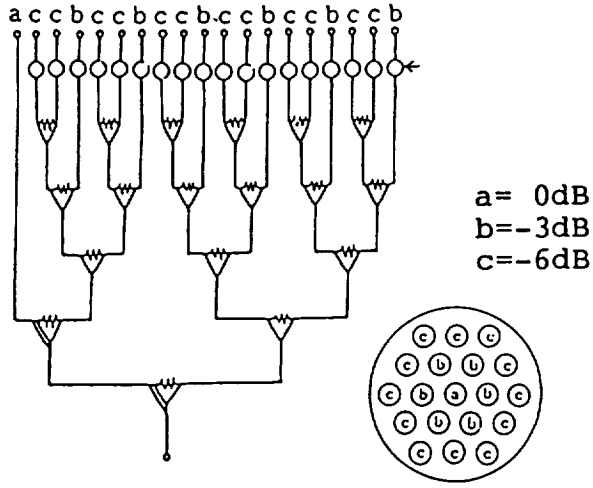

Fig.4 Configuration of Feed Lines.

system is an open loop method, which uses output signals from sensors such as magnetic compass and/or optical gyro. Table 2 shows comparisons of sensors which will be evaluated in the ETS-V experiments. An integrated method using mixture of open and closed methods is also evaluated.

Table.2 Sensors used in the Experiment

Sensor	Accuracy	Resolusion	Cost
Optical Gyro	±0.05° /sec	0.025° /sec	¥1,000,000
Magnetic Sensor	±0.1°	0.1°	¥420,000
Magnetic Compass	±10°	0.25°	¥9,000
Inclination Detector		0.6°	¥340,000
Angular Velocity Detector		0.02° /sec	
Vehicular Speed Detector	400pulses at 60km/h	1pule/6.28cm	

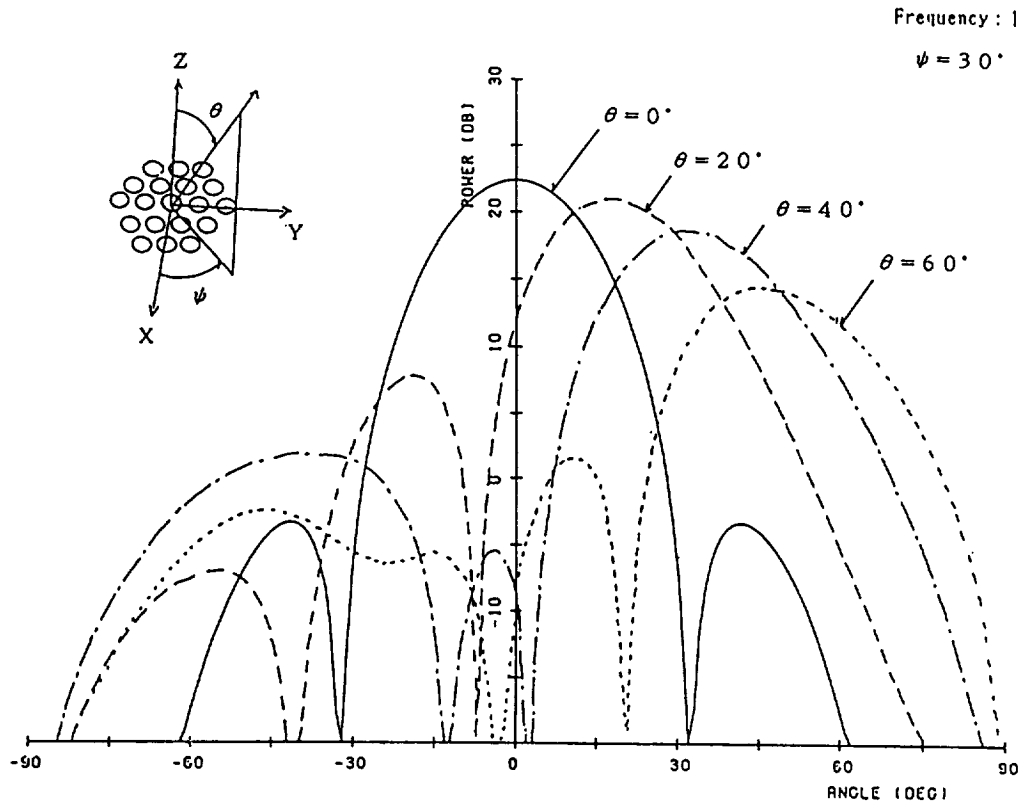

Fig.5 Calucurated Radiation Patterns and Gains.

VI. CONCLUSION

The phased array antenna for land vehicles is under development, and basic characteristics of a prototype are shown. The main aims of developing the phased array antenna are (1) to reduce the tracking error between receiving and transmitting frequencies, (2) to reduce a number of phase shifters in the feed lines and (3) to realize an array fed by electromagnetic coupling.

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